THE EXAMINATION OF OPTICAL MICROVARIABILITY IN RADIO-QUIET AND RADIO-LOUD QSOS

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ABSTRACT

Preliminary results of a continuing search for significant optical microvariations in a selected sample of' radio-quiet and radio-loud quasi-stellar objects are reported. Only 1 object out of 9 radio-quiet QSOS observed shows night to night variations in brightness. on the contrary, all *4* radio-loud QSOS which were observed show evidence for microvariations. The absence of the microvariations does not provide support for theoretical models utilizing discrete events in accretion disks. Therefore, our results are consistent with models based on shocks propagating down relativistic jets as the most likely process responsible for producing most of the microvariations observed in the AGNs.

Subject headings: galaxies:active - galaxies: photometry -- galaxies: variability - quasars: general

1. Introduction

Since the angular dimensions of AGN's nuclei are so small, a reasonable way to investigate the structure and physical conditions near the nucleus is to study the flux variations coming from these objects on the shortest possible time scales.

The existence of microvariations, i.e., variations with durations extending from minutes to days which are either discrete events or parts of longer term trends, in the optical flux of blazars has been well established in BL Lacertae by Miller *et al. (1989)*, in OQ *530* by Carini *et al.* (1990) and in PKS 2155-304 by Carini & Miller (1992). All BL Lacertae objects which have been found to exhibit microvariations, to date, are radio-loud sources and are expected to have relativistic jets which dominate their emission (Bregman 1992). Conversely, it is believed that most radio-quiet AGNs do not have relativistic jets (Antonucci *et al.* 1990) or show only a very weak jet (Miller *et al.* 1993, Kellermann *et al.* 1994).

It has been argued that radio-quiet and radio-loud AGNs fen-m distinct and separate classes (Alloin *et al.* 1992, Wilson & Colbert 1995), At low redshift, radio-loud AGNs are rarely found in spiral host galaxies, but reside in elliptical host galaxies. In addition, very few radio-quiet AGNs are found in elliptical. There is still no clear picture of the cause of the differences in radio emission between these two classes. However, the absence or presence of a very weak jet in radio-quiet AGNs makes these objects suitable for testing the explanations of microvariations which are based on disturbances in accretion disks. Most of the widely contemplated accretion disk based models have been worked out by Wiita *et al. (1991*, 1992, also see Chakrabarti & Wiita 1993, Mangalam & Wiita 1993). They proposed that numerous flares or hot-spots on the accretion disk surrounding the central engine produce the microvariations in AGNs. Thus, if these explanations are correct, one would expect the variations to be independent of the radio properties.

Any detection of optical microvariability in radio-quiet QSOs (hereafter RQQSO) would provide important evidence consistent with the existence of hot-spots in the accretion disk model. The absence of microvariations would support other models. Such results could be interpreted in the context of a shocked jet model, i.e., the relativistic shock moving down the jet and interacting with the irregular structure in the flow (Marscher & Gear 1985, Valtaoja *et al.* 1988, Qian *et al.* 1991).

The purpose of this paper is to present the preliminary results of an ongoing search for significant optical microvariations in a selected sample of radio-quiet and radio-loud QSOs.

2. Observations and Data Reductions

The QSOS we monitored were chosen from the Palomar Bright Quasar Survey and the list of non-OVV AGNs which were monitored and found to exhibit long-term variations in brightness at Rosemary Hill observatory at the University of Florida (Pica *et al.* 1988). Using the list of Schmidt *et al.* (1983), and VLA observations of Kellermann *et al.* (1989), we selected our sample of radio-quiet and radio-loud QSOs.

The objects were selected based on the following criteria: i) m_B <16, in order that one could achieve a reasonable signal-to-noise ratio using a modest exposure time. ii) for the RQQSOs, we confined the ratio R of radio to optical flux density (ratio of total flux density in mJy at 6 cm to optical flux density in mJy at an effective observed wavelength of 4400 Å, computed from the relation described by Kellermann *et al.* (1989)), to be less than 1 in order to assure the objects are radio-quiet. iii) We required that the CCD frame should contain the QSO and at least 3 stars with similar apparent magnitudes. We also tried to observe the object close to the local zenith to minimize airmass induced extinction.

The observations were carried out from March 1994 to November 1994 at Rosemary Hill Observatory (RHO) at the University of Florida and at Lowell Observatory at Flagstaff, Arizona using v and r photometric filters. AIR RHO, the observations were obtained witha Photometries Star I CCD camera located at the f/4 Newtonian focus of the 76 cm reflector behind a 1.5 diopters Barlow lens. This camera has the format of 3$34 X 576 pixels with a pixel size of 23 microns. At Lowell Observatory, RCA CCD camera located at the f/8 Cassegrain direct focus of the 1.09 m reflector was used. This camera has the format of 320 X 512 pixels with a pixel size of 30 microns. Bias, dark current and flat field frames were taken each night to reduce the observational noise. At least one frame in the v-band was taken to complement the r-band frames in order to provide color information.

The observed QSOS are listed in Table 1, along with their 1950 coordinates, red shift, z, apparent B magnitude, R as defined above, and absolute B magnitude.

The data were reduced at the DECstation 5000 system using the IRAF software package. Each exposure is processed through an aper ture photometry routine which reduces the data as if it were produced by a multi-star photometer. Then differential magnitudes can be computed for any pair of stars on the frame. Simultaneous observations of the QSO, comparison stars and the sky background allow one to remove variations which may be due to fluctuations in either atmospheric transparency or extinction.

Carini *et al.* (1991) showed that even for sources with significant underlying galaxy components, any spurious variations introduced by fluctuations in atmospheric seeing or transparency are typically smaller than the observational uncertainties. They examined MCG 8-11-11, which has a very prominent galaxy component, associated with it, reducing the data using the same aperture size and maintaining it over the length of the observations. Examination of the object-comparison star and comparison-check star data sets exhibit no significant difference in standard deviations. Therefore, the variations detected are not the result of variation either in seeing or transparency. Carini *et al. (1992)* examined the plots of magnitude differences between comparison stars of different colors versus airmass, and found that over a large range of airmass, there is no evidence that large color differences in the sets of the comparison stars affect the overall accuracy of the photometry, or introduce systematic variations not intrinsic to the source.

For the observational errors quoted for the present observations, we have fit both the object-comparison star observations and the comparison-check star data with a straight line via a linear least square analysis. In each case, the standard deviation of the data points about the fitted straight line has been calculated. The largest value of the standard deviation, i.e., either from the object-comparison star data or from the comparison star-check star data, is used as the measure of the observational error.

3. Results

The results for the sample of RQQSOs and RLQSOs observed arc summarized in Tables II and III respectively. Column 1 lists the object designation; Column 2, lists the date of the observations; column 3, the observatory utilized for each observation; column 4, the observational error; column 5, the confidence level for the reality of the variability; column 6, the duration of each observation, in hours; and column 7 indicates whether the microvariability was detected in our observations of each source. If no variability for an object is detected within onc night's data set, we also compared the night-to-night brightness changes for each object to determine if variations were present on the time scales of days. The results are discussed below.

Among the 13 QSOS presented here, 9 objects are classified as radio-quiet and 4 objects are classified as radio-loud. In our classification, we defined R value to be less than 1 for the radio-quiet objects.

Radio-Quiet Objects: All of the objects monitored, with the exception of II Zw 175, show no significant variation present within a single night that exceeds the observational errors. Only one of these objects exhibited variations on a night to night basis.

PG 1522+10.2. No variation was detected. This object was also monitored by Gopal-Krishna *et al. (1994)* as a part of a search for optical variability in RQQSOs. They observed this source for a total of 8 hours without detecting any variations.

MKN 877. Observations of this source provided no evidence for rapid variations. However, Neugebauer *et al.* (1989) reported that this source has a high probability of exhibiting low level variations in the near-infrared based on five observations which span a total of 8 years.

II Zw 136. No variations were detected during our observations of this source. Neugebauer *et al.* (1989) reported that this source is also likely to be variable based on six observations obtained in the near-infrared during a 16 year interval.

II Zw 175. No variation was detected during any night that this object was observed. however, when the light curves for night to night data sets were compared, considerable variation was found. Comparison of the September 6 and September 9 data sets shows ~ 0.05 msg. change in the O-C light curve while C-K light curve remained unchanged. We overlayed these two nights' data sets to demonstrate this variation (Figure 1).

Radio-Loud Objects: All of the objects monitored show some evidence of variations.

PHL 658. This object had been monitored optically for 4 years at RHO, and has a documented range of 0.8 magnitude during that time (Pica *et al.*, 1988). It was monitored for 3 nights during the present study. Although no significant variations were detected on two of the nights, a sudden change in brightness of ~ 0.11 magnitude during a 2 hour interval was observed on the night of October 31 and is shown in Figure 2. Since the poor observing conditions on this night makes the C-K data. set noisy, one does not have the same confidence in the reality of this event that one has in other reported detections of microvariations. However, considering the large amplitude of the change, it is reasonable to list this object as exhibiting microvariations.

PG 1241+-176. This object was observed for 3 nights and shows significant variations during every night. The light curve of the May 30 observation is shown in Figure 3. This figure shows a linear trend similar to that seen in many blazars and in other optically violent radio-loud AGNs. The object increased in brightness $\sim$ 0.05 msg. in *3.5* hours.

PG *1718+481.* This object was observed for 2 nights. On the night of August 1, the object faded $\sim$ 0.05 mag in 3.3 hours. The light curve of this data set is shown in Figure 4.

PG 2209+184. It was observed for 2 nights. There is no obvious variation found within each night. However, this object does exhibit night to night variations. The difference in mean magnitude of the O-C data set is $\sim$ 0.03 msg. while the C-K light curves stay at the same level. These two nights' light curves were overlayed and displayed in Figure 5.

4. Discussion

Our preliminary results clearly contrast the variability characteristics for the radio-quiet and radio-loud QSOS. Among the 9 RQQSOs observed, only 1 object exhibits evidence for microvariations. On the contrary, all 4 RLQSOs exhibit some evidence for microvariations. The probability y of detecting microvariations for blazars, if present, is primarily dependent on the length of time the object is monitored. Carini (1990) found that when a blazar is monitored for more than 8 hours, one has a greater than 80% chance of detecting intra-night variability y. H c also reported that there is approximate y a 50% chance of detecting variability when the object is monitored for at least 3 hours. This latter time span corresponds closely to the: minimum time for the monitoring of objects in this sample. Typical rates of change found for blazars are $\sim$ 0.01 msg. per hour. Our observations of PG 1241+176 and PG1718+481 are consistent with these earlier reported results (Carini 1990).

Although the number of objects in our sample of RQQSOs is limited, the lack of detection of microvariations for these objects does not provide support for the models based on the presence of discrete disturbances in accretion disks (e.g. Chakrabarti & Wiita 1993, Mangalam & Wiita 1993) . The microvariation produced in the accretion disk due to hot spots or other instabilities arc expected to be most important when the AGNs are viewed c1osc to face-on, as in the case of the radio-quiet QSOs.

Both the long-term variability and the microvariability can be successfully understood utilizing the concept of shocks propagating down a relativistic jet and producing the optical emission in radio-loud AGNs (e.g. Qian *et al.* 1991, Marscher *et al. 1992,* Gopal-Krishna & Wiita 1992). The present differences in the proposed processes responsible for the microvariability in AGNs can be evaluated when a larger sample of objects are included in our program and monitored for rnicrovariations. Then it will be possible to gain additional insight into the nature of central engines of AGNs. This emphasizes the importance of our ongoing investigation of optical microvariations in the radio-quiet and radio-loud QSOS.

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Table L List of the AGNs observed. The coordinates are 1950.0

SOURCENAME	α	6	z	m_B	R	M_B
PHL 658	000325,0	+15 5307	0.450	15.96	175	-26.19
PG 1011-041	1011 49.0	-040343	0.058	15.49	0.10	-22.22
MKN 734	111911.0	+120046	0.049	14.65	0.15	-22.69
PG 1241+176	124141.0	+17 3729	1.273	15.38	56.4	-26.99
PG 1259+593	125908.2	+59 18 14	0.472	15.60	$\leq$0.10	-26.65
PG 1307+086	130716.2	+08 3547	0.155	15.28	0.10	-24.56
PG 1415+451	141504.3	+45 0957	0.114	15.74	0.17	-23.43
PG 1522+102	152200.0	+10 0903	1.321	15.74	0.13	-28.71
MKN 877	161756.9	+17 3134	0.114	15.53	0.72	-23.64
PG 1718+481	171817.7	+48 0711	1.084	15.33	41.1	-28.70
II Zw 136	21 3001.3	+09 5459	0.061	14.62	0.32	-23.20
PG 2209+ 184	220930.2	+18 2701	0.070	15.86	141	-22.26
H Zw 175	221445.2	+13 5927	0.067	14.98	0.05	-23.04

Table 11. Summary of the observations of the radio-quiet AGNs

OBJECT	DATE	OBSERVATORY	ERROR	CONFIDENCE	DURATION	VARIABLE?
PG 1011-041	03/22/94	RHO	0.011		3.0	No
	04/01/94	"	0.010		3.4	
	04/02/94	"	0.011		3.7	
	04/04/94	"	0.010		3.1	
MKN 734	05/01/94	RHO	0.005	–	2.0	No
	05/02/94	"	0.009		3.7	
	05/06/94	"	0.011		3.7	
PG 1259+593	04/22/94	Lowell	0.009		5.4	No
	04/23/94	"	0.005		4.8	
	04/24/94	"	0.010		3.8	
PG 1307+086	03/31/94	RHO	0.015		3.2	No
	04/01/94	"	0.011		3.3	
	04/02/94	"	0.015		3.4	
	04/20/94	Lowell	0.010		2.6	
PG 1415+451	04/23/94	Lowell	0.005		2.9	No
	04/24/94	"	0.009		3.8	
PG 1522+102	05/00/94	RHO	0.013		3.4	No
MKN 877	06/08/94	RHO	0.008		3.6	No
11 Zw 136	08/29/94	RHO	0.006		6.7	No
	08/30/94	"	0.016		3.9	
	09/05/94	"	0.008	–	7.1	
11 Zw 175	09/06/94	RHO	0.011		4.3	Yes
	09/09/94	"	0.013	–	3.5	
	09/26/94	"	0.013		6.3	
	09/30/94	"	0.012		7.0	

Table 111. Summary of the observations of the radio-loud AGNs

OBJECT	DATE	OBSERVATORY	ERROR	CONFIDENCE	DURATION	VARIABLE?
PHL 656	09/29/94	RHO	0.00s		4.2	Possible
	10/31/94	"	0.016		5.7	
	11/02/94	"	0.012		6.4	
PG 1241+176	05/26/94	RHO	0.009	3.2	3.2	Yes
	05/30/94	"	0.007	3.9	3.6	
	06/08/94	"	0.011	5.5	2.9	
PG 1718+481	08/01/94	RHO	().009	2.6	3.3	Yes
	08/05/94	"	0.011	–	3.8	
PG 2209+184	0S/28/94	RHO	0.009		4.0	Ye.
	09/01/94	"	0.011		3.6	

FIGURE CAPTIONS

Fig. 1- Overlayed r band observations of II Zw 175 obtained 06 September 1994 and 09 September 1994. Observations on 06 September 1994 are denoted by (*), observationson 09 September 1994 are denoted by(A).

Fig. 2-r band observations of PHL 658 obtained 31 October 1994.

Fig. 3-r band observations of PG 1241 +176 obtained 30 May 1994.

Fig. 4- r band observations of PG 171 8+481 obtained 01 August 1994.

Fig. 5-- Overlayed b band observations of PG 2209+185 obtained 28 August 1994 and 01 September 1994. Observations on 28 August 1994 are denoted by (*), observations on 01 September 1994 are denoted y (A) .

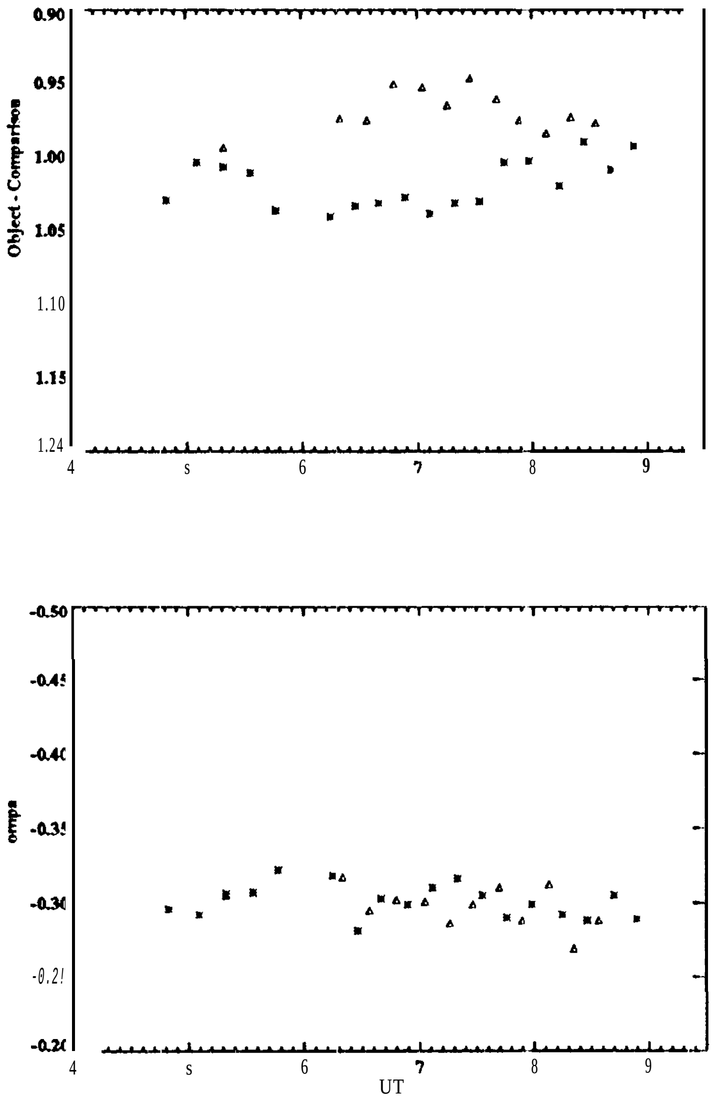
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Figure 1.

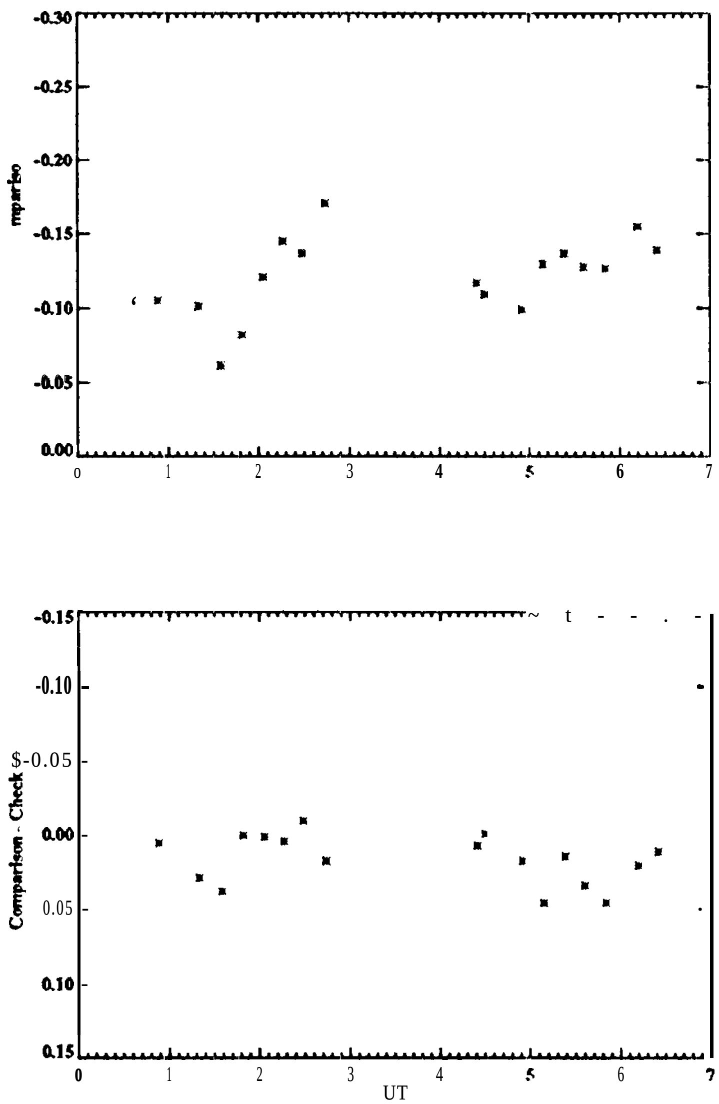
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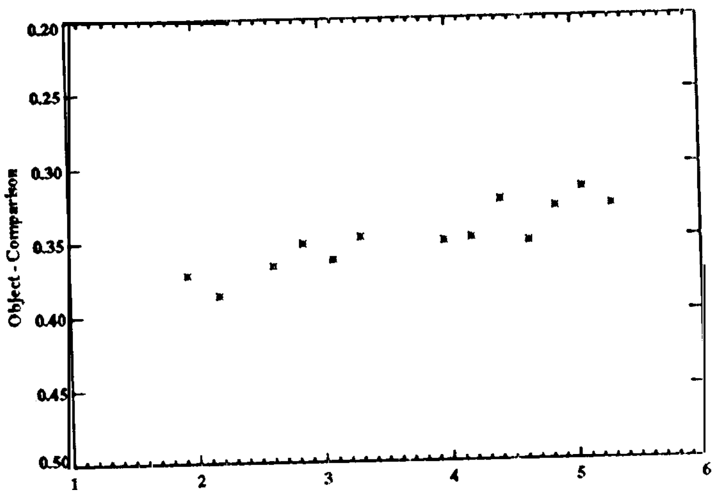
Figure 2.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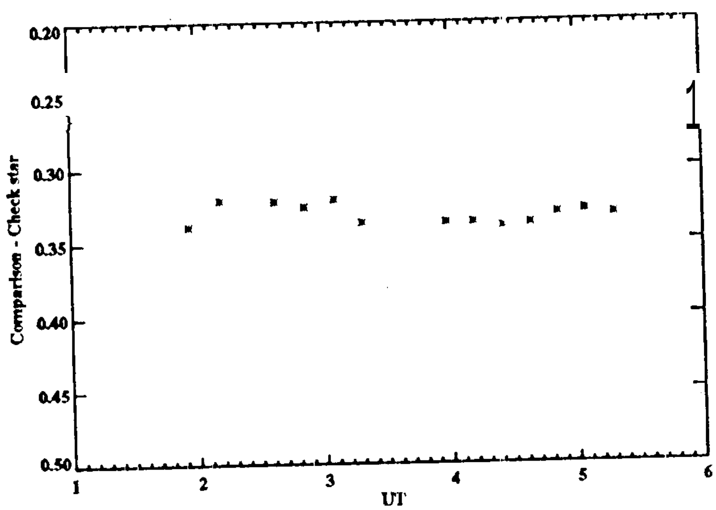
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Figure 3.

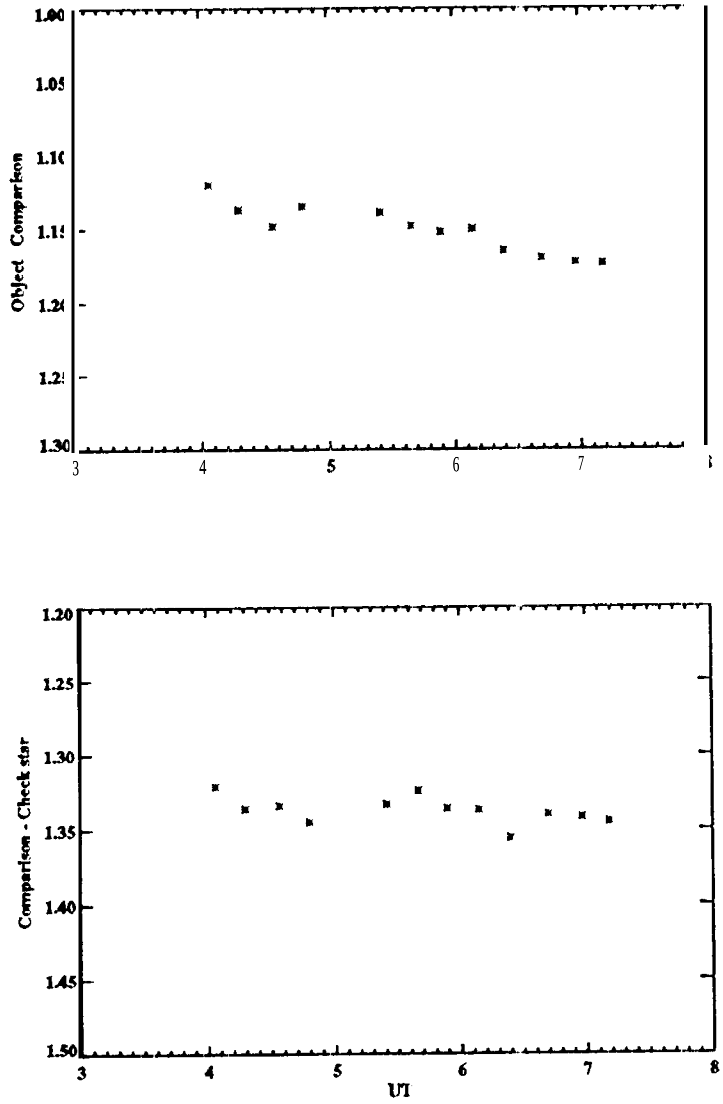

Figure 4.

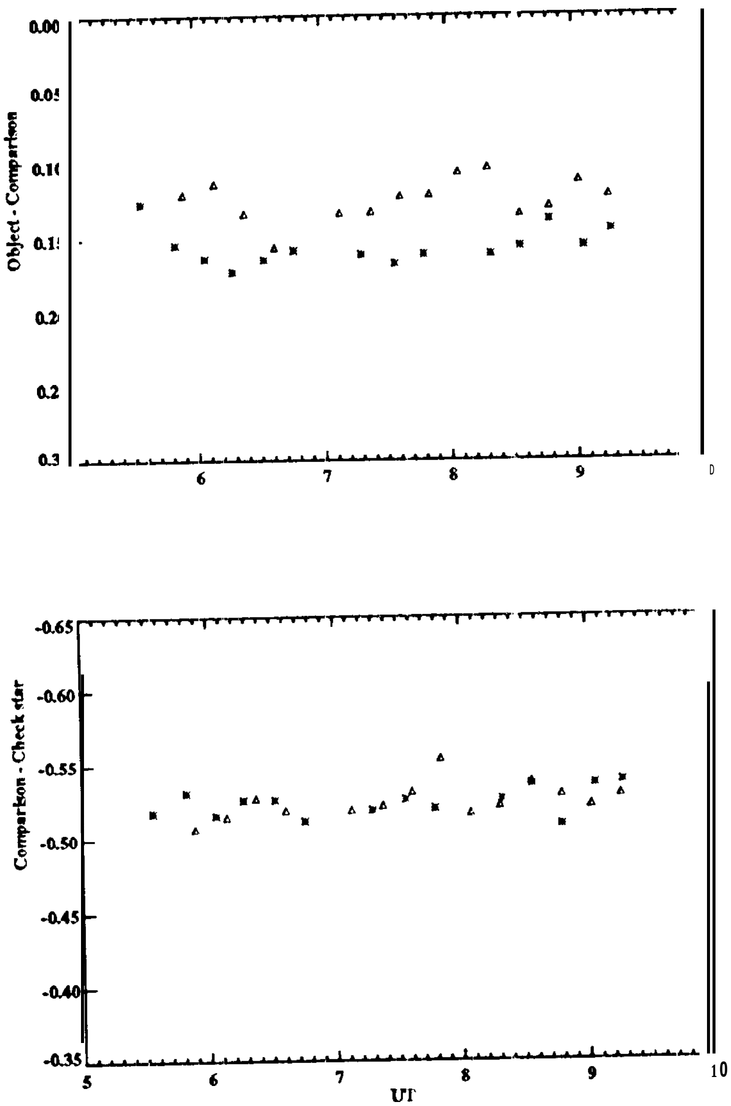
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Figure 5.